MEMORANDUM ON A COLLABORATION IN COMPUTATIONAL ACCELERATOR PHYSICS FOR HIGH INTENSITY BEAMS IN LINACS, RINGS AND CYCLOTRONS

between the

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LANL Advanced Computing Laboratory (ACL)

1 PRESENT SITUATION

1.1 PSI Accelerator Physics and Development Division

The Accelerator Physics and Development Division, in collaboration with other departments of PSI, operates, maintains, and improves the PSI accelerator complex. The accelerators provide the primary beams to PSI's versatile experimental facility for high intensity meson beams, neutron beams, and many other particle beams. Holding the world record for beam power extracted from a cyclotron, PSI is committed to staying at the leading edge of cyclotron technology.

PSI has recently defined future goals and visions concerning operation and upgrade of the PSI accelerator facility. These include:

1. Maintain and improve the present high standard in beam availability
2. Increase the proton beam intensity towards 2mA
3. Perform a feasibility study on how to accelerate 3-mA proton beam current

In addition to these activities, the following projects are of interest concerning accelerator-driven systems (e.g. the energy amplifier and transmutation technologies):

1. development of a liquid-lead target, primarily for the use in the SINQ neutron spallation source
2. conceptual-design work and beam-dynamics studies on a cyclotron facility extrapolating the machines presently in operation at PSI toward 1GeV and 10 mA or more

1.2 LANSCE-Division, Accelerator Physics and Engineering Group (LANSCE-1)

LANL is the site of the Los Alamos Neutron Science Center (LANSCE). LANSCE produces intense sources of pulsed spallation neutrons, which provide the United States scientific community with the capability to perform experiments that support national security and civilian research. Using the world's most powerful proton linac, LANSCE is ideal for research in neutron scattering, neutron physics, and accelerator-driven technologies. LANSCE Division includes the Accelerator Physics and Engineering Group, LANSCE-1, which performs research and development to advance the state of the art in accelerator physics and engineering design and analysis. LANSCE-1 is home to the Los Alamos Accelerator Code Group, which develops, maintains, and distributes accelerator simulation codes used world-wide by the accelerator community.

LANL was one of the principal laboratories leading the DOE Grand Challenge in Computational Accelerator Physics. That project increased accelerator simulation capability 3 to 4 orders of magnitude in terms of problem size and speed of execution. The beam-dynamics codes developed under the Accelerator Grand Challenge have been applied to several projects of international importance, including the LANSCE spallation neutron source linac and the CERN Superconducting Proton Linac. Now LANL is co-leading a multi-laboratory effort that will extend and augment the activities of the Accelerator Grand Challenge. LANSCE-1 is committed to the long-range goal of developing a comprehensive, coherent environment for accelerator simulation.

1.3 LANL Advanced Computing Laboratory

The Advanced Computing Laboratory (ACL) at LANL is devoted to cutting-edge research in high-performance-computing hardware and software. Its mission is to provide support for key large-scale computer simulation projects at LANL and to investigate new approaches to harnessing parallel-computing capabilities and developing scientific-simulation software. The ACL administers a cluster of sixteen 128-way Origin 2000 SMP nodes from Silicon Graphics and an "extreme Linux" cluster of Pentium III machines.

In regard to high-performance software, the ACL has several ongoing projects in the areas of parallel run-time systems, application scripting, and common component architectures. Its largest software effort is the Parallel Object-Oriented Methods and Applications (POOMA) framework, a C++ class library that encapsulates the details of parallel programming for scientific applications in several physics-based data structures and algorithms.

2. GOALS OF THE COLLABORATION

This Memorandum pertains to the initiation of a collaboration in computational accelerator physics for

space-charge-dominated beams in linacs, rings and cyclotrons between the PSI Large Research Facilities Division, PSI Accelerator Physics and Development Group, group LANSCE-1 of LANL's LANSCE Division, and the LANL Advanced Computing Laboratory.

The Collaboration will start now and will be first reviewed prior to the end of 2002. At least one meeting per year will be held for in-depth discussions.

The PSI Accelerator Physics and Development Group, LANSCE-1, and the ACL will collaborate in the area of modelling collective phenomena in intense beams using the latest developments in applied mathematics, computer science and software engineering.

The collaboration will aim to develop a new high-performance simulation capability, beyond the present state of the art, with a long-range goal of modeling intense beam propagation from the injector to the target.

In order to perform detailed, high-precision studies of high intensity beams, one generally has to perform large-scale, three-dimensional particle simulations on parallel supercomputers. In such simulations, the number of macro-particles typically exceeds 100 million. Several types of parallel field solvers (gird-based, tree-based and hybrid) are needed to model a range of boundary conditions and physical situations (such as those involving neighbouring bunches). Furthermore, a variety of field solvers are also needed to systematically study solver performance and accuracy, and to answer questions where it is not obvious if observed effects are due to physics or to the numerical methods employed.

During the course of fulfilling their institutional responsibilities, researchers will collaborate on the following topics:

1. Design, implementation and validation of different multidimensional field solvers: FFT (LANL lead), tree (PSI lead), and hybrid (LANL & PSI)
2. Accurate treatment of space-charge effects under a variety of physical situations: open, periodic, circular and rectangular boundaries (LANL & PSI), neighbouring bunch effects in cyclotrons (PSI lead), beam-beam effects (LANL & PSI)
3. Development of algorithms and software to model space charge in bending magnets (LANL & PSI)
4. Incorporation of the above capabilities into the MAD (Version 9) code, including modifications to make MAD useful as a high intensity linac simulation code (PSI lead)
5. R&D on algorithms and software to model collisional effects in high intensity beams, including self-consistent Fokker-Planck codes (LANL lead)
6. Simulation and interpretation of halo effects in linear and circular machines: linacs (LANL lead), cyclotrons (PSI lead), synchrotrons (LANL & PSI)
7. R&D on direct Vlasov/Poisson solvers (LANL & PSI)
8. Use and development of POOMA (LANL & PSI)

The Collaboration may be amended by mutual agreement by both sides and are subject to the review of the division management of PSI and LANL.

Signed in Villigen/Zuerich Switzerland and Los Alamos, NM, USA, on July 17, 2000.

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